Accelerated functional verification and electrical interface standardization

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A. INTRODUCTION

Digital interfaces within the European space industry are dominated by a lack of unity and standardization. Although ECSS tries to create a common ground, manufacturers and suppliers usually pick the relevant interfaces that suits the case by case needs of the customer next spacecraft mission. These selected interfaces are influenced by heritage (previous use by mission), design requirements (throughput and physical connectivity specifications), and main supplier interface availabilities. Due to this limitation satellite manufacturers and their customers are unable to gain from the benefits of harmonizing the interface options from dozens to a few. These have major benefits, which are currently missed out on, which would allow the ability to reuse equipment across different spacecrafts and ground equipment reducing significantly the design effort, overhead to train engineers and develop suitable code. EGSE Electronic Front End (EFE) costs suffers from these limitation. Suppliers of satellite subsystems such as sensors, actuators, power units, communication units, OBDH etc. require to customize their EGSE EFE to suit the selected interface. The choice of interfaces range from the commonly used MIL1553B, Spacewire, and UART used in scientific and large commercial satellites to CANbus, I2C, and SPI used in the small to medium range commercial satellites. In addition, many ad hoc solutions such as Wizardlink, TTEthernet, Spacefibre etc. have been created to the tackle limitation of existing standards. However, these make the development and use of an EGSE more complicated and expensive. The hardware definition of an interface, along with the lower level software is complemented by different choices of communication protocol that makes the design even harder to implement and reduce any benefit of re-usability. The interface choices currently used and planned in today's space industry can be seen in Fig 1 (Courtesy ESA)

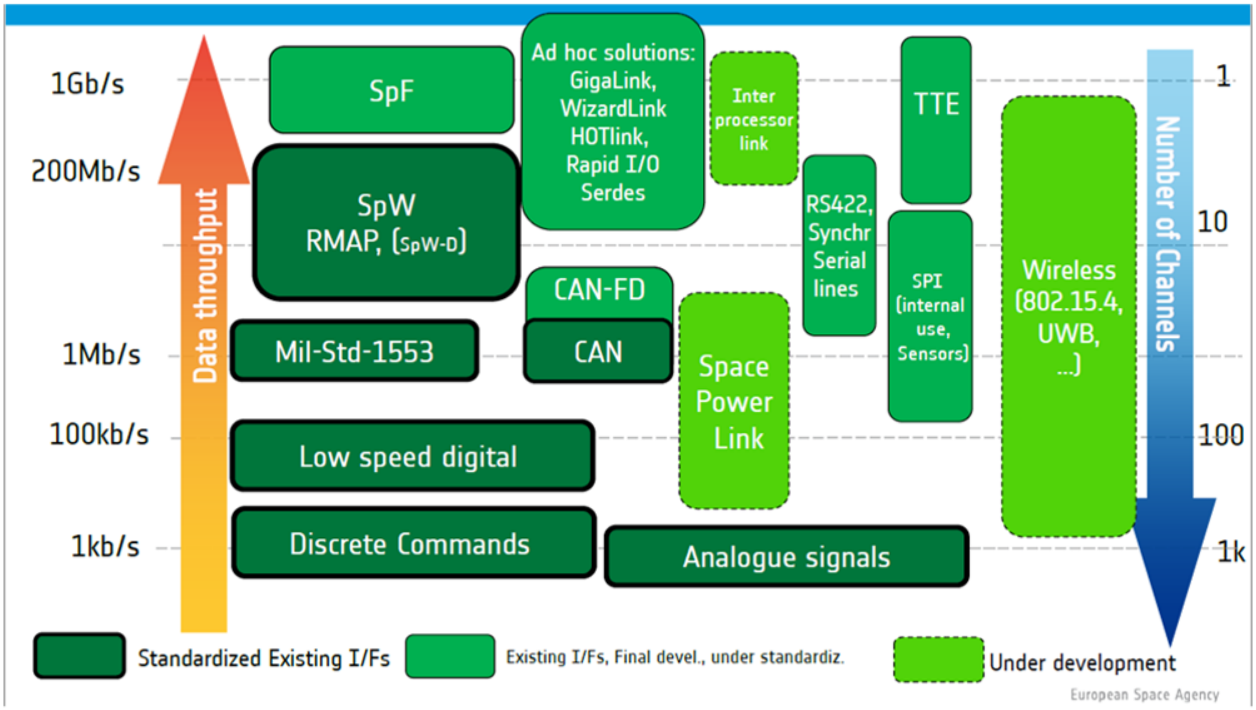

Fig 1. Mapped of space industry used interfaces of data rate vs number of channel

For the last 3 years, Space Products and Innovation UG (SPiN) together with manufacturers (such as Airbus Defence and Space, OHB system, Thales Alenia Space, Qinetiq, suppliers, and others), have been trying to find a solution to reduce the cost and time of EGSE EFE. The goal of this solution encompasses standardization, reusability, modularity, and easy to use. SPiN has developed a product towards this goal that is based on existing and available hardware components, together with a dedicated software solution. The results is the Multipurpose Adapter Generic Interface Connector. This miniature hardware unit can connect to any laptop or server and acts as an EFE to Spacewire, MIL1553B, UART, CANbus, I2C, SPI, and GPIO. It contains embedded software that is able to recognize connected sub-systems and provide the user the ability to communicate with it using a standardized list of commands and telemetry. This means that a command to the same sub-system from different suppliers will have the same effect without the need of writing any code by the user. The communication with the Multipurpose Adapter Generic Interface Connector is available through a Graphical User Interface (GUI) or an Application Program Interface (API). The first can be used to quickly check the sub-system responses to telecommands, and the latter to run scripts and long duration tests via any check-out system.

B. USE CASES

Together with Airbus Defence and Space, SPiN has mapped several use cases where a standardized EFE could reduce time and cost. The following list highlights the process of each test and validation process along with the advantage of using a generic EFE

- **Health check on arrival/incoming inspection**

Content
This check consists out of diagnostic programs provided by the supplier.
Approach

These Health checks are commonly run using a dedicated EGSE EFE from the unit or subsystem supplier containing dedicated diagnostic programs. This type of EGSE does not run script that can be directly used on the check-out system of the satellite, AVM or EM-flat-sat.
Incase if indicated, the 1st health check may also be performed after initial integration on a test bench or subsequent satellite FM models, skipping the checks before integration. In the case of a satellite PFM, a form of health check is more likely to be requested before integration either before and/or after arrival on the integrators premissis.
Comparison
Each dedicated EGSE requires installation time and training of the operators next to the cost of the hardware. The typical time spent in this process is 1-2 weeks per EGSE.
A generic and standardize EFE will allow to directly import the diagnostic program routines from the supplier and the operator would be able to use the same GUI in other missions with the same list of commands and operations.

- **Basic Health Check after integration**

Content
This check consists out of a basic Power On in standby and a mode change where needed. It further may contain a set of operations that will stimulate all external wire/connector connection from the unit.
Approach
A test script or flight operations procedure (FOP) is created by spacecraft operations engineers according to the advices and input of the supplier. The focus is on the items to be tested on the first switch-on after integration. In case of the flight operations program this script is later on adapted by the AIT sw engineer or check-out operator to match the check out system used in-house.
The creation and conversion between the scripts is performed manually and according to the coding language used by the operations engineers (pluto), and AIT (TCL).
Comparison
Typical time spent in this process is 2-4 days per script excluding debugging which adds another 1-3 days.
Using a reusable EFE, the virtual environment can be used for the health check before integration and the basic health check after integration without the need of any re-coding or debugging. In addition scripts such as MOIS procedure from SCOS2000 can be ported directly into the environment.

- **Health check before/after environmental test**

Content
This check consists out of a basic Power On in standby and a mode change where needed. It contains a set of operations that will stimulate all internal wire/connector connections inside the unit.
Any health checks on the processor, memory, and other chips may be included in case they are indicated as a risk factor during environmental testing. The purpose of this test is to discover internal loose contacts and may be extended with a script to stimulate electrically each external connected line where possible. This test purpose is generic to most equipment (stimulate all wires/connectors) and validate that the processor and other Integrate Circuits (IC) are still operational after the test.
Approach
Similar to the basic health check after integration this test uses test scripts which is created from the inputs and advices of the supplier. This test script is directly coded from the document inputs of the supplier or first coded into a Flight Operations Procedure (FOP) and later on adapted to TCL to match the check out system used in-house.
Comparison
The typical time spent in writing the script t is 1-4 days per unit. An additional 1 - 3 days will be spend on debugging.
A modular EFE would allow to run a basic test on all connected units for response and basic command and telemetry response as marked by the supplier. No additional scripting or coding is needed. Using a reusable EFE, the virtual environment can be used for the health check before integration, after

integration, as well as before, during and after environmental test runs, without the need of any re-coding or debugging. In addition scripts such as MOIS procedure from SCOS2000 can be imported directly into the environment.

- **Communication tests**

  Content
  This check consists out of a communication verification between the unit and onboard computer, this may include also the down link and packet verification depending on the test definition point of view.
  Approach
  These tests are performed with identified procedures in the delivered documents from the unit provider, which are transformed/coded into test scripts with appropriate step-by-step procedures by the integrator. Each unit communication test require training of the operator on the test execution and to work with a dedicated unit EGSE EFE where needed.
  Comparison
  The typical time spent in this process is 1-2 day per unit.
  A modular and easy to use EFE would be able to run all communication test commands on every interface through the same simple Graphical User Interface and have the test report automatically generated.

- **software updates**

  Content
  This activity entails the software update of individual units/instruments connected to an OBDH on a satellite platform.
  Approach
  Currently, this activity during AIT is always done using a Software load cable connected to a special skinn-connecter on the satellite, AVM or EM-flat-sat. i the very past unit software updates were classical done by replacing their prom, nowadays are performed by means of Serial or JTAG skin-connector. In the case when in flight there should also be an ability to do software updates using TMTC via the OBC or OBDH.
  Comparison
  The typical time spent in this process is 1-3 day per unit.
  A generic and modular EFE would be able to send digital data in any format on any interface and record the incoming information while displaying it in real-time. This will save the need to a dedicated cables and EFE for the software upload activity and it does not require any changes to the EGSE operating software.

- **Anomaly investigation**

  Content
  This activity entails the retrieval and analysis of TMTC and report packages
  Approach
  During tests, analytical /report packets are requested by TC wherever needed. These are then analysed either online or later offline. Currently,
  Comparison
  Most analyses are currently done offline as report packages are requested and downloaded first and afterwards retrieved from the check-out system. This also may include the decoding of packets as the packet may not be in the data base of the check-out EGSE.
  A generic and modular EFE will be able to record the incoming information and to display in real-time the decomposed packets of any unit at any time as this conversion data is directly provided via the suppliers drivers of the unit.

C. NEXT STEP

In addition to being a digital conduit for data, this new type of EFE can be enhanced in the future to cover also electrical tests during AIT, for example:

- **The Electrical integration of a unit**

  Content
  The process of a unit to be connected to a prior mechanically integrated OBC/OBDH and PCDU includes:

  1. Bonding Resistance of the unit/setup
  2. Grounding and Isolation Harness Check
  3. Unconnected Power Check
  4. Unconnected digital signal/Sts lines Check
  5. Connected Power Check
  6. Interface Synchronization Check
  7. MIL/space wire etc-Bus Check

  Approach

  A. Cables are connected to the pcdu and OBDH (for test 2, 3, 4)
  B. The test bench (flatsat) or satellite pcdu and OBDH is powered to do unconnected signal/line checks using break out box or a test adaptor. This test include, signal voltage and resistance. In addition , for test 3 & 4, commanding of OBDH/PCDU is needed.
  C. The bench is powered down after the check.
  D. The unit is electrically connected (for test 5, 6, 7)
  E. The test bench or satellite unit is powered and switched ON during tests 5, 6 and 7.
  F. The unit is switched on in first mode or stby mode using test scripts on the check-out system.
  G. A Basic Health Check is performed and/or a script to stimulate electrically each external connected line where possible.(this is the same indicator test which is used before and after environmental tests to discover loose connectors.)

  For Step B, Airbus uses Integrated Defensive Aids Suite (IDAS) to check individual cables. A test script needs to be developed for each cable (normally done on the EM Flat Sat). Once programmed the same cable can be re-tested with significant reduced effort. It reduces time on PFM AIT and constellation models.

  The modular EFE at this moment will already be able to perform step B in conjunction with IDAS and steps C, E, F, G.

  In the future the modular EFE in combination with onboard flight Multipurpose Adapter Generic Interface Connectors will be able to perform steps B to G in a plug and play approach.

- **Electrical architecture diagnostics**

  Identifying root causes for failures can be of great help in production lines for mega constellation. Each unit can suffer from several failures along the connection lines for power, on-board handling units and electrical interface units. The current diagnostic tools require manual work to identify the locations to be tested. In the aviation industry, there are examples of automated onboard diagnostic systems that instruct the user to check certain locations and feedback the results to identify if the cause has been found or the diagnosis should continue.

The modular EFE in combination with onboard flight Multipurpose Adapter Generic Interface Connectors will be able in the future to run diagnostic check on all cables of the electrical architecture without the need of switching on the units. It will be the first step of making the electrical architecture of a satellite a full seperate subsystem.

- **European Ground Systems – Common Core (EGS-CC)**

  "The EGS-CC is a European initiative to develop a common infrastructure to support space systems monitoring and control in pre- and post-launch phases for all mission types. This is expected to bring a number of benefits, such as the seamless transition from spacecraft Assembly, Integration and Testing (AIT) to mission operations, reduce cost and risk, support the modernisation of legacy systems and promote the exchange of ancillary implementations across organizations. The initiative is being performed as collaboration between ESA, European National Agencies and European Industry" [1]

  EGS-CC will be a strong benefit in how we optimize the operations and testing phases using the monitoring & control model (MCM) (i.e during AIT, egse, ground infrastructure and space segment). What EGS-CC does not optimize is the pre-work effort from selecting units, adapting the S/C electrical architecture to unit dependant bus protocols, pre-preparing test scripts and flight operation procedures for units and how the TMTC database is populated with the inputs from the suppliers of each unit .

  For example, when the connection of AIT (Phase D) and operations (Phase E) will become closer, there will still be a need for a generic software driver database that can be used to operate units in both phases. Each driver needs to contain the define of the telemetry & commands associated with the connected unit, the expected response telemetry for each command, the protocol to which unit to send data, the hardware specifications (connecters, cables, delay times), and digital specification (data rate, handshakes, unit ID). These drivers specification are currently not part of the check-out systems and are usually unit specific embedded in the dedicated EGSE.

  The generic EFE proposed in this paper will optimize all labour outside the EGS-CC focus as mentioned above by hosting all unit drivers of all suppliers. This generic EFE will strongly complement check-out systems like EGS-CC able to retrieve the driver and test any connected sub-system. An additional inherent benefit is that when a unit (e.g. Star tracker) is replaced by a model from a different supplier the AIT tests can continue without the need of re-validating the TMTC database and changing any test scripts.

D. **CONCLUSION:**

This paper focuses on the current AIT use cases featuring a dedicated EGSE. Each test requires specific training and operating time to complete which is a significant driver on the work effort and scheduling, but is also hinders scalability. These processes are mostly routine and generic for each satellite. Until recently there was no need to change this approach. However, today shorter lead times in commercial space industry are strongly needed, due to its investment schemes and the growing market of satellite constellations. Satellite integrators and their customers will have to think differently to stay ahead in today's market.
For example, satellite constellations require a very short phase D process and in some cases only a few days for each unit.

Much time and money are spent on building the perfect AIT process for these constellations with dedicated equipments to meet the requirements of testing and time spent. Usually these requirements are focused on the current satellite design which limit the possibility to adapt the same AIT process for another constellation.
The uses cases described above & the viability of a generic EFE allows to take proven check-out processes and implement them on every satellite (independent from the type of satellite) to accelerate the time and perform electrical integration with its functional verification in around 2 days per unit.
Although this has not yet been proven analytically using a standard electrical interface, this is proposed to be implemented in the near future and the paper serves as a baseline for the next step of a full study using the already developed Multipurpose Adapter Generic Interface Connector and generic standardize EFE from SPiN.

REFERENCES

[1] EGS-CC SYSTEM - http://www.egscc.esa.int/about.html